# UNDERSTORY PLANT COMMUNITY RESPONSE TO SEASON OF BURN IN NATURAL LONGLEAF PINE FORESTS

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## ABSTRACT

A season of burn study was initiated in 1973 on the Escambia Experimental Forest, near Brewton, Alabama. All study plots were established in 14-year-old longleaf pine (*Pinus palustris*) stands. Treatments consisted of biennial burns in winter, spring, and summer, plus a no-burn check. Objectives of the current study were to determine composition and structure of understory plant communities after 22 years of seasonal burning, identify changes since last sampling in 1982, and assess the structure of the communities that stabilized under each treatment regime. There were 114 species on biennial winter-burned plots, compared to 104 on spring- and summer-burned and 84 with no burning. The woody understory biomass (<1 centimeter diameter at breast height) increased with all treatments compared with 1982. Grass and legume biomass increased with winter and spring burning. Forb biomass decreased across treatments.

*keywords:* biomass, longleaf pine, *Pinus palustris,* plant response, prescribed fire, south Alabama, understory.

*Citation:* Kush, J.S., R.S. Meldahl, and W.D. Boyer. 2000. Understory plant community response to season of burn in natural longleaf pine forests. Pages 32–39 *in* W. Keith Moser and Cynthia F. Moser (eds.). Fire and forest ecology: innovative silviculture and vegetation management. Tall Timbers Fire Ecology Conference Proceedings, No. 21. Tall Timbers Research Station, Tallahassee, FL.

## INTRODUCTION

Prior to the arrival of European settlers in the United States, natural communities dominated by longleaf pine and maintained by periodic fire occurred throughout most of the southern Coastal Plain (Frost 1993). Bartram (1791), an early traveler through the Southeast, wrote about these communities: "This plain is mostly a forest of the great long-leaved pine (*P. palustris* Linn.), the earth covered with grass, interspersed with an infinite variety of herbaceous plants, and embellished with extensive savannahs, always green, sparkling with ponds of water . . ."

The landscape that Bartram and early settlers encountered was largely the result of frequent fire. Low-intensity, non-lethal fires swept through the presettlement longleaf savannas at intervals ranging from 1–10 years (Mattoon 1922, Chapman 1932, Christensen 1981). These fires were ignited by a combination of lightning strikes (Komarek 1974) and aboriginal incendiarism (Robbins and Myers 1992). The frequent fires had an incredible impact on the flora of the longleaf landscape. A mesic longleaf woodland may contain 140 vascular species per 1,000 square meters, the largest values reported for the temperate Western Hemisphere (Peet and Allard 1993).

It has been well documented that in the absence of frequent burning, the diverse ground cover of the longleaf landscape is replaced by hardwood trees and shrubs (Christensen 1981, Streng and Harcombe 1982). The importance of frequent burning in these systems has been realized, but questions have arisen concerning season of burn. Komarek (1964) and Robbins and Meyers (1992) concluded that most lightning-ignited fires occurred during the growing season. However, much of the prescribed burning done in the Southeast is conducted during the winter. Among the reasons are the cooler temperatures associated with that time of year, more predictable winds, and potentially less damage to the trees and regeneration.

Streng et al. (1993) provided an excellent literature review of research studies evaluating the effects of season of burn in longleaf pine forests. One of these studies came from research conducted on long-term burning plots located in south Alabama (Boyer 1983, 1987). Research was begun in 1973 to determine the effects of understory hardwood control treatments on the growth of overstory longleaf pine and development of understory vegetation. One of the original study objectives was to follow understory plant succession under different seasonal burning regimes. Boyer (1995) reported on responses of ground cover before treatment and 7 and 9 years after treatments. Although treatments have continued, lack of resources prevented sampling understory vegetation after 1982. This study, a continuation of Boyer's earlier work, examines effects of 23 years of different seasonal biennial burns (or no burn) on ground cover vegetation in natural longleaf pine forests.

## STUDY AREA

The study was conducted at the Escambia Experimental Forest in south central Escambia County, Alabama (31°01'N; 87°04'W). The forest is maintained by the U.S. Department of Agriculture, Forest Service,

Table 1. Ground cover biomass changes with time (all plots) from a 23-year-old season of burn study in south Alabama.

| Year | Stand Basal Area (square meters per hectare) | BIOMASS (kilograms per hectare) | | | | |
|---|---|---|---|---|---|---|
| | | Woody | Herbaceous | Total | Organic litter | Total |
| 1973 | 6.9 | 508.5 | 422.2 | 930.7 | 8,310.4 | 9,241.1 |
| 1980 | 13.8 | 698.9 | 483.8 | 1,182.7 | 10,759.8 | 11,942.5 |
| 1982 | 17.2 | 636.6 | 387.5 | 1,023.7 | 9,255.7 | 10,279.4 |
| 1996 | 22.2 | 966.6 | 99.3 | 1,065.9 | 20,333.9 | 21,399.8 |

Southern Research Station, in cooperation with T.R. Miller Mill Company.

The climate is humid and mild with plentiful rainfall well distributed throughout the year. The warmest months are July and August with average daily maximum and minimum temperatures of 33° and 20°C, respectively. The coldest months are December and January with average daily temperatures of 18° and 3°C, respectively. The growing season is 250 days. Annual precipitation averages 156 centimeters. October is the driest month.

The predominant soil series on this coastal plain site was the Troup (Grossarenic Paleudult, loamy siliceous thermic) with some Wagram, Dothan, and Fuquay represented. These soils formed in unconsolidated marine sediments of loamy sands, sandy loams, and sandy clay loams. They are very low in natural fertility and organic-matter content.

## METHODS

Boyer (1987, 1991, 1993, 1994, 1995) described the establishment, methods, and treatment regimes for this study. Treatments consisted of biennial burns in winter, spring, and summer, plus a no-burn check. Each burning treatment was combined with 3 supplemental hardwood control treatments: chemical injection of all hardwood stems in 1973, hand-clearing of all hardwood stems >1.3 meters in height in 1973 and periodically thereafter as needed, and an untreated check. The study area had not been burned since 1962, so all season of burn plots were first given a winter conditioning burn in January 1974. Boyer reported on effects of treatments on growth of the longleaf pine overstory (1987, 1994); the effects of a single chemical treatment, with and without fire, on development of woody vegetation (1991); and development of hardwoods in relation to season of biennial burns (1993).

In late September-early October 1996, living material <1 centimeter diameter at breast height (DBH) was destructively sampled from 9 0.893-square meter sample plots per treatment plot to coincide with the sampling done in 1982. The vegetation was sorted by species using the taxonomy of several authorities (Grelen and Duvall 1966, Radford et al. 1968, Clewell 1985, Godfrey 1988, Kartesz 1994). It was oven-dried at 70°C for 72 hours and weighed. Organic litter was collected from 1 30.5-square centimeter subplot within each of these sample plots, dried, and weighed. The winter season burn was last conducted in February 1996, the spring in May 1995, and the summer in July 1995.

Information on understory composition and biomass by components was compared to the earlier results from this study. The number of species, species frequency and biomass, and percent biomass were examined among the different season of burns.

## RESULTS AND DISCUSSION

Ground cover biomass was highly variable and changed substantially over the last 23 years. Estimates of biomass by year and component (type) are given in Table 1 (this is an update of Table 1 from Boyer 1995). In terms of average weights, as stand age and basal area increased over time, the organic litter component increased greatly, the woody component increased slightly, and herbaceous component declined. We hypothesize this large increase in organic litter may be due to 2 major factors. The first factor concerns the decrease between 1980 and 1982. The lower 1982 litter weight might have been the result of a hotter than normal fire or lower than normal litter fall prior to sampling. The dramatic increase in litter weight from 1982 to 1996 might also be due to a major increase in the amount of woody debris added to the organic litter over the last 14 years of the study. Some of the debris may have been added during the 1990 thinning operation. The analysis of raw biomass weights indicated that after 23 years of constant burning regimes, equilibrium had not been reached on the plots.

An examination of the biomass data by burning treatment suggested some consistent trends from 1982–1996 (Table 2). Woody, total green, and organic litter components increased for all burning treatments while the forb component uniformly decreased. Legumes, a potentially important factor for wildlife food and maintaining or improving site quality, decreased on the no-burn treatments. Legume biomass increased with the winter burning treatment, remained the same with the spring burning treatment, but decreased with summer burning where low values in 1982 declined further in 1996. Grass biomass did not show any consistent trends. Organic litter was the largest component of understory biomass and increased substantially for all burning treatments.

One hundred forty-three species were identified in ground cover in the early autumn sampling (Table 3). The lowest number of species occurred on the no-burn treatment and the highest on the winter burn. The high-

Table 2. Effect of burning treatments on understory biomass (kilograms per hectare) in 1982 and 1996 and percent change (%) from 1982–1996 from a 23-year-old season of burn study in south Alabama.

| Component | 1982 | 1996 | Percent change |
|---|---|---|---|
| No Burn | | | |
| Woody | 1,180.5 | 2,027.7 | +71.8 |
| Grasses | 43.7 | 10.6 | −75.7 |
| Forbs | 68.3 | 13.1 | −80.8 |
| Legumes | 4.5 | 2.0 | −55.6 |
| Total Green | 1,297.0 | 2,053.4 | +58.3 |
| Litter | 16,874.0 | 42,778.2 | +153.5 |
| Total Biomass | 18,171.0 | 44,831.6 | +146.7 |
| Winter | | | |
| Woody | 385.3 | 571.3 | +48.3 |
| Grasses | 199.4 | 207.5 | +4.1 |
| Forbs | 327.0 | 184.0 | −43.7 |
| Legumes | 14.6 | 24.7 | +69.2 |
| Total Green | 926.3 | 987.5 | +6.6 |
| Litter | 4,560.6 | 12,382.0 | +171.5 |
| Total Biomass | 5,486.9 | 13,369.5 | +143.7 |
| Spring | | | |
| Woody | 509.6 | 611.9 | +20.1 |
| Grasses | 172.5 | 179.8 | +4.2 |
| Forbs | 183.7 | 182.7 | −0.5 |
| Legumes | 17.9 | 18.1 | +1.1 |
| Total Green | 883.7 | 992.5 | +12.3 |
| Litter | 8,059.5 | 12,814.0 | +59.0 |
| Total Biomass | 8,943.2 | 13,806.5 | +54.4 |
| Summer | | | |
| Woody | 471.5 | 655.6 | +39.0 |
| Grasses | 177.0 | 112.4 | −36.5 |
| Forbs | 333.8 | 240.7 | −27.9 |
| Legumes | 6.7 | 3.9 | −41.8 |
| Total Green | 989.0 | 1,012.6 | +2.4 |
| Litter | 7,557.8 | 13,361.5 | +76.8 |
| Total Biomass | 8,546.8 | 14,374.1 | +68.2 |

est number of woody species and lowest number of herbaceous species were associated with the no-burn treatment. The spring and summer burning treatments had the lowest number of woody species but were not all that different from the winter and no burn even after 23 years of biennial burning treatments.

The burning treatments were examined for the most common species, by component, in the ground cover (Appendix 1). These species' biomass and percent total biomass were determined for each burning treatment (Appendix 2).

## Woody Species

Inkberry (*Ilex glabra*), dwarf huckleberry (*Gaylussacia dumosa*), and blackberry (*Rubus* spp.) were the most common species, each occurring on >30% of all plots. The predominant woody component in the no-burn treatment was shrubs and vines. Yellow jessamine (*Gelsemium sempervirens*) and inkberry were the dominant species, totaling 61% of the biomass. Blackberry and several greenbrier species (*Smilax* spp.) were frequent within this treatment but accounted for very little of the biomass. The frequency and biomass of potential overstory tree species were very low. Response to the burning treatments was variable. Inkberry dominated the summer burn plots, accounting for 69% of the biomass. Summer burning reduced the frequency and biomass of vines and potential overstory species compared to the other burning treatments. One outlier was weak-leaf yucca (*Yucca flaccida*) on 1 plot, accounting for 6% of the biomass. Responses to the winter and spring burns were similar. Inkberry constituted 34% and 37%, respectively, of the biomass. Vines accounted for another 22% and 27%. The oaks (*Quercus* spp.) contributed to the biomass of each burning treatment, but their frequency was low and they did not dominate any plots.

Table 3. Number of species from a 23-year-old season of burn study in south Alabama by vegetation component harvested in autumn 1996 for each burning treatment.

| Component | No burn | Winter | Spring | Summer | Total |
|---|---|---|---|---|---|
| Woody | 40 | 35 | 32 | 32 | 48 |
| Forb | 25 | 47 | 40 | 42 | 56 |
| Grass | 10 | 16 | 13 | 16 | 20 |
| Legume | 9 | 16 | 19 | 14 | 19 |
| Total | 84 | 114 | 104 | 104 | 143 |

## Forbs

Frequency of species was very low on the no-burn plots. Queen's root (*Stillingia sylvatica*), mallow (*Hibiscus aculeatus*), and bushy aster (*Aster dumoses*) and white-topped aster (*A. tortifolius*) were the most common species on these plots. These species accounted for 70% of the total forb biomass with 47% of that total belonging to mallow. Several species were very frequent on the plots treated with fire. Golden aster (*Chrysopsis mariana*), a member of the Composite family, was the major species found within the burning treatments, accounting for approximately 28% of the winter burn biomass, 25% of the summer burn, and 46% of the spring burn. Species in this family (members of the genera *Aster, Carphephorus, Cirsium, Coreopsis, Elephantopus, Erechtites, Eupatorium, Gnaphalium, Helenium, Helianthus, Hieracium, Ionactis, Liatris, Lobelia, Rudbeckia, Silphium, Solidago, Veronia*) constituted 84%, 85%, and 70% of the forb biomass in winter, spring, and summer burning treatments, respectively, and 28% in the no-burn treatment. Deer's-tongue (*Carphephorus odoratissimus*) was the other major component within the winter and summer burning treatments. There was an obvious absence of southern bracken (*Pteridium aquilinium*) on the fire-treated plots. Several dried stems were noted, but very little living material was left at the time of sampling.

## Legumes

The predominant legumes were partridge-pea (*Chamaecrista fasciculata*), pencil flower (*Stylosanthes biflora*), and milk-pea (*Galactia erecta*) across all burning treatments. Legumes rarely occurred on the no-burn plots and were present on ≤8% of the sample plots. Butterfly-pea (*Clitoria mariana*), and milk-pea were the dominant species on the winter burn plots, accounting for >50% of the legume biomass. On the

spring burn plots, milk-pea was the major species, along with several species of beggar's lice (*Desmodium* spp.), and pencil flower. Several species were prevalent on the summer burn plots. Dollarleaf rhynchosia (*Rhynchosia reniformis*), occurring on only 12% of the plots, constituted 27% of the legume biomass. Other important species were beggar's lice (*Desmodium strictum*), and pencil flower. It is unknown why the frequency and biomass of the legumes in the summer-burned treatment were lower compared to the other burning treatments. It may be that sampling during the spring or summer would have produced more legume biomass.

### Grasses

The major grass species across all burning treatments was slender bluestem (*Schizachyrium tenerum*). It was the most frequently occurring species and accounted for ≥60% of the biomass for all treatments. Arrowfeather three-awn (*Aristida purpurascens*), downy oatgrass (*Danthonia sericea*), and beaked panicum (*Panicum anceps*) were the other common grasses. These four species accounted for 84%, 91%, 91%, and 82% of the grass biomass on the no-burn, winter, spring, and summer burn treatments.

## MANAGEMENT IMPLICATIONS

Several significant changes have occurred in response to different seasonal burns in a 1974 longleaf pine understory plant community study last reported in 1982. Woody biomass and litter had increased in the no-burn treatment while the grass, forb, and legume component decreased. The biomass of the woody and legume component substantially increased in the winter burning treatments while the forb component decreased. There was very little change with the spring burning treatment except for an increase in the woody component. Summer burns resulted in substantial decreases to all components except for the woody species.

If forest managers are interested in species diversity, biennial winter burning had 114 species compared to 104 for both spring and summer fires. If the goal is to produce the most biomass in legumes for wildlife food, winter fires produced 27% and 84% more legume biomass than did spring and summers fires, respectively. There was very little difference in total biomass between the burning treatments if controlling competition or fuel reduction is the major management goal. Boyer (*this volume*) discussed the long-term effects of these biennial burns on the growth of longleaf pine in this study.

This study was conducted in the late summer-early autumn, which corresponded to the timing of ground cover sampling in 1982. It remains to be seen what differences there might be if the sampling were conducted during the spring or summer. The results indicate winter burning may be just as beneficial for any management decisions as growing-season burns.

## ACKNOWLEDGMENTS

We would like to thank several individuals for their efforts. G. Ward, B. Thompson, R. Sampson, N. Gupta, J. Rayamajhi, W. Williams, and D. Shaw provided many hours of "back-breaking" assistance in the field and laboratory. V. Crouch and N. Maceina provided assistance with plant identification, and L. Pitt spent many hours doing data entry. The U.S. Department of Agriculture, Forest Service provided funding.

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Appendix 1. Percent occurrence (%) for species harvested in autumn 1996 for each burning treatment from a 23-year-old season of burn study in south Alabama (n = 81).

| Species | No burn | Winter | Spring | Summer |
|---|---|---|---|---|
| Woody | | | | |
| *Acer rubrum* | 2.47 | 0 | 0 | 0 |
| *Berlandiera pumilia* | 0 | 17.28 | 2.47 | 6.17 |
| *Carya pallida* | 0 | 1.23 | 1.23 | 0 |
| *Ceanothus americanus* | 9.88 | 19.75 | 18.52 | 14.18 |
| *Cornus florida* | 13.58 | 4.94 | 1.23 | 1.23 |
| *Diospyros virginiana* | 4.94 | 3.70 | 7.41 | 8.64 |
| *Gaylussacia dumosa* | 37.04 | 65.43 | 39.51 | 45.68 |
| *Gaylussacia frondosa* | 20.99 | 24.69 | 23.46 | 23.46 |
| *Gelsemium sempervirens* | 76.54 | 20.99 | 25.93 | 8.64 |
| *Hypericum crus-andreae* | 0 | 1.23 | 0 | 0 |
| *Hypericum hypercoides* | 0 | 18.52 | 22.22 | 11.11 |
| *Ilex coriacea* | 1.23 | 0 | 0 | 0 |
| *Ilex decidua* | 9.88 | 4.94 | 4.94 | 4.94 |
| *Ilex glabra* | 64.20 | 34.57 | 30.86 | 64.20 |
| *Ilex opaca* | 1.23 | 0 | 1.23 | 0 |
| *Ilex vomitoria* | 0 | 0 | 0 | 1.23 |
| *Licania michauxii* | 6.17 | 29.63 | 13.58 | 6.17 |
| *Liquidambar styraciflua* | 1.23 | 0 | 0 | 0 |
| *Lonicera japonica* | 16.05 | 0 | 1.23 | 0 |
| *Magnolia grandiflora* | 1.23 | 0 | 0 | 0 |
| *Myrica cerifera* | 7.40 | 11.11 | 18.52 | 34.57 |
| *Nyssa sylvatica* | 2.47 | 0 | 0 | 0 |
| *Pinus palustris* | 1.23 | 0 | 3.70 | 0 |
| *Prunus serotina* | 1.23 | 1.23 | 0 | 2.47 |
| *Quercus falcata* | 6.17 | 1.23 | 1.23 | 3.70 |
| *Quercus incana* | 4.94 | 9.88 | 8.64 | 2.47 |
| *Quercus laevis* | 3.70 | 2.47 | 0 | 1.23 |
| *Quercus laurifolia* | 8.64 | 7.41 | 2.47 | 1.23 |
| *Quercus margarattiae* | 7.40 | 2.47 | 1.23 | 8.64 |
| *Quercus marilandica* | 7.40 | 18.52 | 7.41 | 0 |
| *Quercus nigra* | 8.64 | 7.41 | 13.58 | 3.70 |
| *Rhus copallina* | 1.23 | 20.99 | 45.68 | 3.70 |
| *Rubus* spp. | 37.04 | 79.01 | 48.15 | 55.56 |
| *Sassafras albidum* | 2.47 | 9.88 | 8.64 | 4.94 |
| *Smilax bona-nox* | 1.23 | 1.23 | 0 | 1.23 |
| *Smilax glauca* | 37.04 | 13.58 | 16.05 | 22.22 |
| *Smilax laurifolia* | 1.23 | 0 | 0 | 0 |
| *Smilax pumila* | 34.58 | 24.69 | 13.58 | 20.99 |
| *Smilax rotundifolia* | 7.41 | 8.64 | 3.70 | 0 |
| *Symplocos tinctoria* | 0 | 3.70 | 0 | 1.23 |
| *Toxicodendron pubescens* | 2.47 | 7.41 | 16.05 | 1.23 |
| *Toxicodendron radicans* | 1.23 | 0 | 0 | 0 |
| *Vaccinium arboreum* | 7.41 | 9.88 | 1.23 | 2.47 |
| *Vaccinium myrsinites* | 20.99 | 14.81 | 18.52 | 20.99 |
| *Vaccinium stamineum* | 2.47 | 1.23 | 0 | 0 |
| *Vaccinium tenellum* | 0 | 0 | 4.94 | 2.47 |
| *Vitis rotundifolia* | 11.11 | 7.41 | 0 | 0 |
| *Yucca flaccida* | 0 | 0 | 0 | 1.23 |

Appendix 1. Continued.

| Species | No burn | Winter | Spring | Summer |
|---|---|---|---|---|
| Forbs | | | | |
| *Acalypha gracilens* | 0 | 27.16 | 25.93 | 19.75 |
| *Agalinis filicaulia* | 0 | 0 | 1.23 | 0 |
| *Asclepias amplexicaulis* | 0 | 1.23 | 0 | 0 |
| *Aster adnatus* | 4.94 | 27.16 | 25.93 | 23.46 |
| *Aster concolor* | 0 | 2.47 | 0 | 0 |
| *Aster dumoses* | 8.64 | 65.43 | 38.27 | 40.74 |
| *Aster paludosus* | 1.23 | 9.88 | 12.35 | 0 |
| *Aster patens* | 1.23 | 41.98 | 4.94 | 18.52 |
| *Aster tortifolius* | 11.11 | 64.20 | 39.51 | 34.57 |
| *Aureolaria pectinata* | 0 | 1.23 | 3.70 | 2.47 |
| *Carphephorus odoratissimus* | 6.17 | 46.91 | 45.68 | 83.95 |
| *Chrysopsis gossypina* | 1.23 | 14.81 | 49.38 | 32.10 |
| *Chrysopsis mariana* | 2.47 | 72.84 | 79.01 | 75.31 |
| *Cirsium horridulum* | 0 | 1.23 | 1.23 | 4.94 |
| *Cnidoscolus stimulosus* | 2.47 | 4.94 | 4.94 | 3.70 |
| *Coreopsis major* | 7.41 | 40.74 | 34.58 | 23.46 |
| *Croton argyranthemus* | 3.70 | 18.52 | 38.27 | 25.93 |
| *Dioda teres* | 0 | 1.23 | 0 | 0 |
| *Elephantopus tomentosus* | 2.47 | 54.32 | 56.79 | 37.04 |
| *Erechtites hieracifolia* | 0 | 1.23 | 0 | 0 |
| *Eryngium yuccifolium* | 0 | 0 | 1.23 | 1.23 |
| *Eupatorium album* | 0 | 3.70 | 2.47 | 1.23 |
| *Eupatorium compositifolium* | 0 | 4.94 | 1.23 | 1.23 |
| *Eupatorium pilosum* | 4.94 | 13.58 | 13.58 | 11.11 |
| *Eupatorium rotundifolium* | 0 | 0 | 0 | 1.23 |
| *Euphorbia corollata* | 1.23 | 38.27 | 20.99 | 28.40 |
| *Galium pilosum* | 0 | 4.94 | 2.47 | 0 |
| *Gentiana autumnalis* | 0 | 1.23 | 0 | 0 |
| *Gnaphalium purpureum* | 0 | 0 | 3.70 | 3.70 |
| *Habenaria ciliaris* | 0 | 1.23 | 1.23 | 3.70 |
| *Helenium amarum* | 1.23 | 1.23 | 2.47 | 0 |
| *Helianthus angustifolius* | 0 | 0 | 0 | 1.23 |
| *Hieracium gronovii* | 0 | 0 | 0 | 1.23 |
| *Hibiscus aculeatus* | 12.35 | 7.41 | 18.52 | 20.99 |
| *Houstonia procumbens* | 1.23 | 2.47 | 24.69 | 22.22 |
| *Ionactis linariifolius* | 1.23 | 1.23 | 0 | 0 |
| *Iris verna verna* | 0 | 1.23 | 0 | 0 |
| *Liatris graminifilia* | 1.23 | 43.21 | 19.75 | 38.27 |
| *Liatris squarrosa* | 1.23 | 27.16 | 12.35 | 11.11 |
| *Liatris squarrulosa* | 0 | 3.70 | 1.23 | 2.47 |
| *Lobelia puberula* | 2.47 | 27.16 | 16.05 | 14.82 |
| *Lycopodiella alopecuroides* | 0 | 0 | 1.23 | 6.17 |
| *Monotropa uniflora* | 0 | 0 | 0 | 1.23 |
| *Polygala lutea* | 0 | 1.23 | 0 | 4.94 |
| *Pteridium aquilinum* | 2.47 | 17.28 | 1.23 | 22.22 |
| *Rudbeckia hirta* | 1.23 | 37.04 | 45.68 | 40.74 |
| *Seyemeria cassioides* | 0 | 6.17 | 4.94 | 6.17 |
| *Silphium compositum* | 1.23 | 14.81 | 6.17 | 14.81 |

Appendix 1. Continued.

| Species | No burn | Winter | Spring | Summer |
|---|---|---|---|---|
| *Solidago odora* | 0 | 13.58 | 28.40 | 24.69 |
| *Stellaria media* | 0 | 3.70 | 9.88 | 6.17 |
| *Stillingia sylvatica* | 37.04 | 79.01 | 48.15 | 60.49 |
| *Tragia urens* | 0 | 0 | 0 | 2.47 |
| *Trichostema setaceum* | 0 | 1.23 | 0 | 0 |
| *Veronia angustifolia* | 0 | 2.47 | 0 | 0 |
| *Viola pedata* | 0 | 4.94 | 7.41 | 3.70 |
| *Xyris ambigua* | 0 | 2.47 | 0 | 0 |
| Legumes | | | | |
| *Centrosema virginianum* | 0 | 2.47 | 3.70 | 1.23 |
| *Chamaecrista fasciculata* | 2.47 | 24.69 | 19.75 | 1.23 |
| *Chamaecrista nictitans* | 0 | 4.94 | 3.70 | 0 |
| *Clitoria mariana* | 2.47 | 33.33 | 22.22 | 7.40 |
| *Crotalaria purshii* | 1.23 | 13.58 | 13.58 | 3.70 |
| *Desmodium ciliare* | 1.23 | 0 | 6.17 | 1.23 |
| *Desmodium marilandicum* | 0 | 1.23 | 4.94 | 0 |
| *Demsodium obtusum* | 0 | 0 | 1.23 | 0 |
| *Desmodium strictum* | 0 | 14.81 | 16.05 | 4.94 |
| *Galactia erecta* | 3.70 | 37.04 | 43.21 | 14.81 |
| *Lespedeza capitata* | 1.23 | 6.17 | 4.94 | 6.17 |
| *Lespedeza hirta* | 0 | 6.17 | 3.70 | 3.70 |
| *Lespedeza repens* | 0 | 9.88 | 1.23 | 4.94 |
| *Orbexilum pedunculatum psoralidides* | 0 | 7.40 | 4.94 | 3.70 |
| *Rhynchosia reniformis* | 1.23 | 22.22 | 24.69 | 12.35 |

Appendix 1. Continued.

| Species | No burn | Winter | Spring | Summer |
|---|---|---|---|---|
| *Strophostyles umbellata* | 0 | 0 | 1.23 | 0 |
| *Stylosanthes biflora* | 7.40 | 32.10 | 33.33 | 25.96 |
| *Tephrosia chrysophylla* | 0 | 0 | 1.23 | 0 |
| *Tephrosia spicata* | 0 | 1.23 | 0 | 0 |
| *Tephrosia virginiana* | 1.23 | 14.81 | 16.05 | 11.11 |
| Grasses | | | | |
| *Andropogon virginicus* | 1.23 | 3.70 | 2.47 | 8.64 |
| *Anthaenantia villosa* | 1.23 | 23.46 | 13.58 | 25.93 |
| *Aristida purpurascens* | 8.64 | 48.15 | 39.51 | 35.80 |
| *Bulbostylis capillaris* | 0 | 0 | 0 | 1.23 |
| *Danthonia sericea* | 8.64 | 62.96 | 50.62 | 64.20 |
| *Gymnopogon ambiguus* | 1.23 | 32.10 | 14.81 | 14.81 |
| *Muhlenbergia capillaris trichopodes* | 0 | 1.23 | 0 | 0 |
| *Panicum anceps* | 11.11 | 45.68 | 38.27 | 33.33 |
| *Panicum sphaerocarpon* | 0 | 13.58 | 13.58 | 19.75 |
| *Panicum virgatum* | 1.23 | 6.17 | 20.99 | 24.69 |
| *Paspalum floridanum* | 2.47 | 23.46 | 25.93 | 14.81 |
| *Paspalum laeve* | 0 | 0 | 0 | 1.23 |
| *Schizachyrium scoparium* | 0 | 1.23 | 1.23 | 0 |
| *Schizachyrium tenerum* | 17.28 | 87.65 | 82.72 | 76.54 |
| *Scleria ciliata* | 0 | 2.47 | 0 | 1.23 |
| *Sorghastrum nutans* | 0 | 2.47 | 0 | 1.23 |
| *Sporobolus junceus* | 0 | 0 | 1.23 | 0 |
| *Tridens flavus* | 0 | 1.23 | 0 | 3.70 |
| *Zigadenus densus* | 1.23 | 3.70 | 3.70 | 4.94 |

Appendix 2. Dry-weight biomass (kilograms per hectare) and percent total biomass (%) for species harvested in autumn 1996 from a 23-year-old season of burn study in south Alabama. A (—) indicates the species was absent. A (+) indicates biomass was <1% (n = 81).

| Species | No burn | Winter | Spring | Summer |
|---|---|---|---|---|
| Woody | | | | |
| *Acer rubrum* | 4.36/+ | — | — | — |
| *Berlandiera pumilia* | — | 2.82/+ | 0.21/+ | 0.36/+ |
| *Carya pallida* | — | 0.37/+ | 2.49/+ | — |
| *Ceanothus americanus* | 1.45/+ | 8.57/1.5 | 9.60/1.6 | 5.8/0.9 |
| *Cornus florida* | 21.57/1.1 | 20.50/3.6 | 0.29/+ | 0.02/+ |
| *Diospyros virginiana* | 40.99/2.0 | 6.99/1.2 | 6.98/1.1 | 4.70/0.7 |
| *Gaylussacia dumosa* | 4.70/+ | 30.34/5.3 | 8.38/1.4 | 9.7/1.5 |
| *Gaylussacia frondosa* | 6.76/+ | 11.57/2.0 | 9.11/1.5 | 9.7/1.5 |
| *Gelsemium sempervirens* | 464.37/22.9 | 19.12/3.3 | 115.97/19.0 | 3.9/0.6 |
| *Hypericum crus-andreae* | — | 0.23/+ | — | — |
| *Hypericum hypercoides* | — | 0.70/+ | 1.01/+ | 0.32/+ |
| *Ilex coriacea* | 0.01/+ | — | — | — |
| *Ilex decidua* | 164.90/8.1 | 0.52/+ | 0.88/+ | 0.23/+ |
| *Ilex glabra* | 790.08/39.0 | 195.20/34.2 | 228.59/37.4 | 453.60/69.2 |
| *Ilex opaca* | 35.54/1.8 | — | 0.01/+ | — |
| *Ilex vomitoria* | — | — | — | 0.76/+ |
| *Licania michauxii* | 2.89/+ | 47.56/8.3 | 15.04/2.5 | 2.04/+ |
| *Liquidambar styraciflua* | 4.08/+ | — | — | — |
| *Lonicera japonica* | 17.76/+ | — | 0.02/+ | — |
| *Magnolia grandiflora* | 49.94/2.5 | — | — | — |
| *Myrica cerifera* | 7.48/+ | 17.59/3.1 | 9.76/1.6 | 35.45/5.4 |
| *Nyssa sylvatica* | 19.22/+ | — | — | — |
| *Pinus palustris* | 0.23/+ | — | 0.43/+ | — |
| *Prunus serotina* | 0.13/+ | 0.02/+ | — | 7.59/1.2 |
| *Quercus falcata* | 32.44/1.6 | 1.02/+ | 0.22/+ | 1.50/+ |
| *Quercus incana* | 5.26/+ | 11.73/2.1 | 4.9/+ | 3.47/+ |
| *Quercus laevis* | 7.28/+ | 7.10/1.2 | — | 1.68/+ |
| *Quercus laurifolia* | 7.72/+ | 1.56/+ | 0.27/+ | 0.26/+ |
| *Quercus margarattiae* | 8.52/+ | 61.80/10.8 | 45.40/7.4 | 4.85/+ |
| *Quercus marilandica* | 11.14/+ | 1.90/+ | 0.72/+ | — |
| *Quercus nigra* | 132.76/6.5 | 0.27/+ | 1.34/+ | 0.79/+ |
| *Rhus copallina* | 0.35/+ | 13.58/2.4 | 54.57/8.9 | 1.24/+ |
| *Rubus* spp. | 6.62/+ | 32.2/5.6 | 22.95/3.8 | 24.11/3.7 |
| *Sassafras albidum* | 1.24/+ | 3.33/+ | 20.48/3.3 | 1.30/+ |
| *Smilax bona-nox* | 0.56/+ | 0.15/+ | — | 0.19/+ |
| *Smilax glauca* | 21.38/1.1 | 1.96/+ | 4.53/+ | 9.42/1.4 |
| *Smilax laurifolia* | 1.98/+ | — | — | — |
| *Smilax pumila* | 13.61/+ | 12.79/2.2 | 14.98/2.4 | 10.48/1.6 |
| *Smilax rotundifolia* | 3.09/+ | 5.32/+ | 2.49/+ | — |
| *Symplocos tinctoria* | — | 16.84/2.9 | — | 10.48/1.6 |
| *Toxicodendron pubescens* | 0.18/+ | 2.51/+ | 2.14/+ | 0.18/+ |
| *Toxicodendron radicans* | 0.04/+ | — | — | — |
| *Vaccinium arboreum* | 70.93/3.5 | 8.60/1.5 | 0.03/+ | 0.44/+ |
| *Vaccinium myrsinites* | 40.72/2.0 | 23.88/4.2 | 28.00/4.6 | 11.11/1.7 |
| *Vaccinium stamineum* | 0.44/+ | 0.05/+ | — | — |
| *Vaccinium tenellum* | — | — | 0.09/+ | 0.22/+ |
| *Vitis rotundifolia* | 24.99/1.2 | 2.55/+ | — | — |
| *Yucca flaccida* | — | — | — | 39.5/6.0 |
| Forbs | | | | |
| *Acalypha gracilens* | — | 1.58/+ | 0.45/+ | 0.82/+ |
| *Agalinis filicaulia* | — | — | 0.03/+ | — |
| *Asclepias amplexicaulis* | — | 0.02/+ | — | — |
| *Aster adnatus* | 0.15/1.1 | 1.48/+ | 1.30/+ | 0.62/+ |
| *Aster concolor* | — | 0.33/+ | — | — |
| *Aster dumoses* | 0.46/3.5 | 9.37/5.1 | 6.41/3.5 | 3.44/1.4 |
| *Aster paludosus* | 0.36/2.8 | 0.66/+ | 0.81/+ | 0.45/+ |
| *Aster patens* | 0.03/+ | 6.00/3.3 | 0.83/+ | 2.62/1.1 |
| *Aster tortifolius* | 0.86/6.6 | 5.14/2.8 | 1.60/+ | 2.52/1.0 |
| *Aureolaria pectinata* | — | 0.06/+ | 0.24/+ | 0.05/+ |
| *Carphephorus odoratissimus* | 0.64/4.9 | 22.79/12.4 | 6.81/3.7 | 49.66/20.6 |
| *Chrysopsis gossypina* | 0.03/+ | 1.46/+ | 22.81/12.5 | 16.99/7.1 |
| *Chrysopsis mariana* | 0.03/+ | 51.70/28.1 | 83.57/45.7 | 59.9/24.9 |
| *Cirsium horridulum* | — | 0.03/+ | 1.10/+ | 1.72/+ |
| *Cnidoscolus stimulosus* | 0.02/+ | 0.04/+ | 0.11/+ | 0.04/+ |
| *Coreopsis major* | 0.05/+ | 2.97/1.6 | 1.90/1.0 | 1.86/+ |
| *Croton argyranthemus* | 0.29/2.2 | 1.49/+ | 3.63/2.0 | 0.85/+ |
| *Dioda teres* | — | 0.01/+ | — | — |
| *Elephantopus tomentosus* | 0.05/+ | 18.26/9.9 | 13.83/7.6 | 9.87/4.1 |
| *Erechtites hieracifolia* | — | 1.02/+ | — | — |
| *Eryngium yuccifolium* | — | — | 1.65/+ | 0.77/+ |
| *Eupatorium album* | — | 1.01/+ | 0.47/+ | 0.22/+ |
| *Eupatorium compositifolium* | — | 8.49/4.6 | 0.67/+ | 0.08/+ |

Appendix 2. Continued.

| Species | No burn | Winter | Spring | Summer |
|---|---|---|---|---|
| *Eupatorium pilosum* | 0.82/6.2 | 4.13/2.2 | 0.57/+ | 1.01/+ |
| *Eupatorium rotundifolium* | — | — | — | 0.02/+ |
| *Euphorbia corollata* | 0.28/2.1 | 3.47/1.9 | 0.79/+ | 2.04/+ |
| *Galium pilosum* | — | 0.23/+ | 0.71/+ | — |
| *Gentiana autumnalis* | — | 0.23/+ | — | — |
| *Gnaphalium purpureum* | — | — | 0.68/+ | 0.64/+ |
| *Habenaria ciliaris* | — | 0.45/+ | 0.01/+ | — |
| *Helenium amarum* | 0.10/+ | 0.05/+ | 0.11/+ | 0.34/+ |
| *Helianthus angustifolius* | — | — | — | 0.01/+ |
| *Hieracium gronovii* | — | — | — | 0.07/+ |
| *Hibiscus aculeatus* | 6.20/47.3 | 1.59/+ | 12.24/6.7 | 40.58/16.9 |
| *Houstonia procumbens* | 0.04/+ | 0.07/+ | 1.42/+ | 0.69/+ |
| *Ionactis linariifolius* | 0.12/+ | 0.44/+ | — | — |
| *Iris verna verna* | — | 0.23/+ | — | — |
| *Liatris graminifilia* | 0.01/+ | 3.69/2.0 | 0.80/+ | 2.47/1.0 |
| *Liatris squarrosa* | 0.01/+ | 4.01/2.2 | 0.76/+ | 0.38/+ |
| *Liatris squarrulosa* | — | 0.21/+ | 0.05/+ | 0.07/+ |
| *Lobelia puberula* | 0.46/3.5 | 2.37/1.3 | 1.65/+ | 1.02/+ |
| *Lycopodiella alopecuroides* | — | — | 0.43/+ | 15.99/6.6 |
| *Monotropa uniflora* | — | — | — | 0.05/+ |
| *Polygala lutea* | — | 0.01/+ | — | 0.50/+ |
| *Pteridium aquilinum* | 0.23/1.7 | 6.92/3.8 | 0.03/+ | 2.16/+ |
| *Rudbeckia hirta* | 0.03/+ | 3.14/1.7 | 7.92/4.3 | 5.26/2.2 |
| *Seyemeria cassioides* | — | 0.58/+ | 1.18/+ | 1.52/+ |
| *Silphium compositum* | 0.14/1.1 | 8.13/4.4 | 0.84/+ | 8.18/3.4 |
| *Solidago odora* | — | 1.09/+ | 2.18/1.2 | 1.80/+ |
| *Stellaria media* | — | 0.02/+ | 0.17/+ | 0.05/+ |
| *Stillingia sylvatica* | 1.70/13.0 | 6.52/3.5 | 1.94/1.1 | 3.27/1.4 |
| *Tragia urens* | — | — | — | 0.01/+ |
| *Trichostema setaceum* | — | 0.03/+ | — | — |
| *Veronia angustifolia* | — | 0.02/+ | — | — |
| *Viola pedata* | — | 0.07/+ | 0.02/+ | 0.03/+ |
| *Xyris ambigua* | — | 2.40/1.3 | — | — |
| Legumes | | | | |
| *Centrosema virginianum* | — | 0.04/+ | 0.33/1.8 | 0.01/+ |
| *Chamaecrista fasciculata* | 0.27/13.5 | 2.14/8.6 | 0.98/5.4 | 0.03/+ |
| *Chamaecrista nictitans* | — | 0.11/+ | 0.02/+ | — |
| *Clitoria mariana* | 0.01/+ | 6.88/27.9 | 1.28/7.1 | 0.06/1.6 |
| *Crotalaria purshii* | 0.02/1.2 | 1.13/4.6 | 0.95/5.3 | 0.25/6.4 |
| *Desmodium ciliare* | 0.15/7.5 | — | 0.84/4.6 | 0.01/+ |
| *Desmodium marilandicum* | — | 0.10/+ | 2.06/11.4 | — |
| *Demsodium obtusum* | — | — | 0.01/+ | — |
| *Desmodium strictum* | — | 2.39/9.7 | 1.39/7.7 | 0.63/16.2 |
| *Galactia erecta* | 1.26/62.8 | 6.09/24.7 | 5.87/32.6 | 0.48/12.3 |
| *Lespedeza capitata* | 0.02/1.0 | 0.08/+ | 0.05/+ | 0.08/2.0 |
| *Lespedeza hirta* | — | 1.76/7.1 | 0.70/3.9 | 0.10/2.5 |
| *Lespedeza repens* | — | 0.13/+ | 0.01/+ | 0.02/+ |
| *Orbexilum pedunculatum psoralidides* | — | 1.05/4.3 | 0.11/+ | 0.26/6.8 |
| *Rhynchosia reniformis* | 0.03/1.5 | 0.60/2.4 | 0.80/4.4 | 1.06/27.3 |
| *Strophostyles umbellata* | — | — | 0.24/1.3 | — |
| *Stylosanthes biflora* | 0.18/8.8 | 0.88/3.6 | 1.70/9.4 | 0.41/10.6 |
| *Tephrosia chrysophylla* | — | — | 0.01/+ | — |
| *Tephrosia spicata* | — | 0.10/+ | — | — |
| *Tephrosia virginiana* | 0.07/3.3 | 1.23/5.0 | 0.74/4.1 | 0.50/12.8 |
| Grasses | | | | |
| *Andropogon virginicus* | 0.36/3.4 | 1.03/+ | 1.30/+ | 3.11/2.8 |
| *Anthaenantia villosa* | 0.28/2.7 | 3.28/1.6 | 1.57/+ | 4.86/4.3 |
| *Aristida purpurascens* | 0.25/2.4 | 16.86/8.1 | 23.42/13.0 | 10.14/9.0 |
| *Bulbostylis capillaris* | — | — | — | 0.53/+ |
| *Danthonia sericea* | 0.81/7.6 | 17.30/8.3 | 8.90/4.9 | 8.56/7.6 |
| *Gymnopogon ambiguus* | 0.01/+ | 3.74/1.8 | 1.7/+ | 0.70/+ |
| *Muhlenbergia capillaris trichopodes* | — | 0.72/+ | — | — |
| *Panicum anceps* | 1.02/9.6 | 5.80/2.8 | 9.00/5.0 | 4.94/4.4 |
| *Panicum sphaerocarpon* | — | 1.79/+ | 1.58/+ | 2.61/2.3 |
| *Panicum virgatum* | 0.23/2.2 | 0.59/+ | 3.78/2.1 | 4.61/4.1 |
| *Paspalum floridanum* | 0.75/7.1 | 6.77/3.3 | 5.52/3.1 | 1.19/1.1 |
| *Paspalum laeve* | — | — | — | 0.85/+ |
| *Schizachyrium scoparium* | — | 0.02/+ | 0.17/+ | — |
| *Schizachyrium tenerum* | 6.80/64.2 | 148.30/71.5 | 121.98/67.8 | 68.67/61.1 |
| *Scleria ciliata* | — | 0.05/+ | — | 0.11/+ |
| *Sorghastrum nutans* | — | 0.61/+ | — | 0.96/+ |
| *Sporobolus junceus* | — | — | 0.13/+ | — |
| *Tridens flavus* | — | 0.25/+ | — | 0.12/+ |
| *Zigadenus densus* | 0.09/+ | 0.41/+ | 0.78/+ | 0.38/+ |